BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B70 07015

SUBJECT: A Parametric Study of a Two Stage, High Mass Fraction, High Isp Expendable Launch Vehicle - Case 105-6

DATE: July 7, 1970

FROM: J. J. Schoch

ABSTRACT

The characteristics of a high mass fraction, high specific impulse two stage expendable launch vehicle were determined for comparison with low cost launch vehicle concepts such as described by the Boeing MCD study.

The results presented in the form of curves show that for a very high second stage mass fraction and Isp, the first stage gross weight becomes practically insensitive to both first stage specific impulse and first stage mass fraction.

As an alternative application, the payload capability was derived for the first stage of the previously defined launch vehicle using the standard SIVB as a second stage.

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MEMORANDUM FOR FILE

INTRODUCTION

The following parametric study was performed to show the characteristics of a high mass fraction, high specific impulse two stage expendable launch vehicle for comparison with low cost launch vehicle concepts such as described by the Boeing MCD study (Reference 1).

DISCUSSION

The parametric study covers a two stage expendable launch vehicle. The calculations were made using the "Computer Program for Launch Vehicle Sizing and Sensitivities" by A. E. Marks (Reference 2). The following parameter ranges were considered.

Mass Fraction 1st Stage:	0.86 to 0.90
Mass Fraction 2nd Stage:	0.88 to 0.92
Specific Impulse 1st Stage: (SL)	355 sec and 360 sec
Specific Impulse 1st Stage: (VAC)	445 sec and 455 sec
Specific Impulse 2nd Stage: (VAC)	420 to 455 sec

All calculations are based on a total ideal ΔV = 30,490 ft/sec, which is sufficient to go to a 55° 270 nm earth orbit. In each case the program divided the total ΔV between the two stages in such a manner as to provide a minimum gross liftoff weight for a given payload.

Gross liftoff weight of the whole vehicle, of the first, and of the second stage are plotted on Figures 1, 2, and 3 as a function of second stage specific impulse. The gross weights apply to a 50,000 lb payload but can be scaled proportionally for any other payload. It can be seen from the curves that for increasing second stage specific impulse, the first stage gross weight decreases rapidly. This is due to the fact

that for increasing second stage specific impulse the optimum ideal ΔV split calculation attributes an increasingly larger percentage of the total ΔV to the second stage thereby reducing the size of the first stage and increasing the size of the second stage.

Reference is now made to Figure 2 showing first stage gross liftoff weight vs second stage specific impulse. For a value of second stage specific impulse of 455 sec and a second stage mass fraction of 0.92, the first stage gross weight is practically insensitive to both the first stage specific impulse and first stage mass fraction. This is due to the fact that for the high value of second stage specific impulse and mass fraction, the first stage provides an increasingly smaller percentage of the total ΔV. Referring to these same parameters on Figure 1, (a second stage mass fraction of 0.92 and specific impulse of 455 sec) it is seen that vehicle gross weight varies relatively little, less than 10%, when changing the first stage mass fraction from 0.86 to 0.90. Also, from Figure 3, the second stage gross weight decreases approximately 25% when the first stage mass fraction increases from 0.86 to 0.90.

Figure 4 shows exchange ratios relating to the gross weight of each of the two stages, the gross weight of the whole vehicle, and the first stage ΔV to the percent change in first stage mass fraction. The exchange ratios are plotted as a function of first stage mass fraction while all the other parameters are held constant.

As an alternative application concept, the payload capability was derived for the first stage of the previously defined vehicle using the standard SIVB as a second stage. Since the SIVB is a fixed configuration, the weight of the first stage was assumed to vary as needed. Figure 5 shows the reciprocal of the growth factor (i.e., payload divided by liftoff weight) versus the payload. The maximum of each of these curves indicates for each of the specific impulses and mass fractions the size of the first stage giving the minimum liftoff gross weight for a given payload.

Vehicle gross weight is plotted vs payload on Figure 6. The lowest growth factor is indicated for each curve.

J. J. Schoch

1013-JJS-baw

Attachments
Figures 1-6

REFERENCES

1. SAMSO-TR-24, "Minimum Cost Design - Space Launch Vehicle Design/Costing Study (U)", M. T. Braun, The Boeing Company, New Orleans, Louisiana, February, 1970, CONFIDENTIAL.

2. Computer Program for Launch Vehicle Sizing and Sensitivities - Case 105-4 , A. E. Marks, To be published.

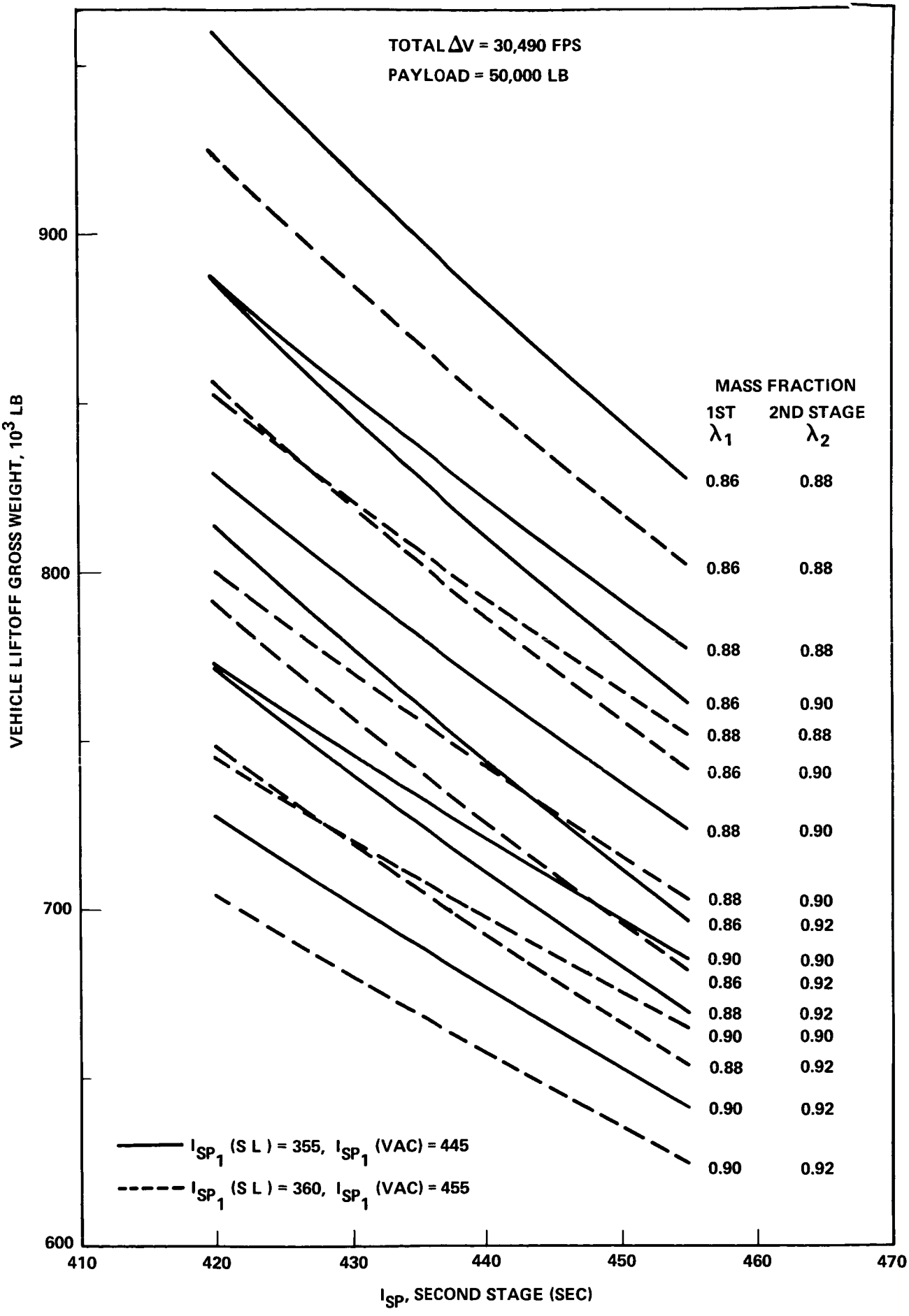

FIGURE 1 · LIFTOFF GROSS WEIGHT OF 2-STAGE VEHICLE vs I_{SP}, SECOND STAGE

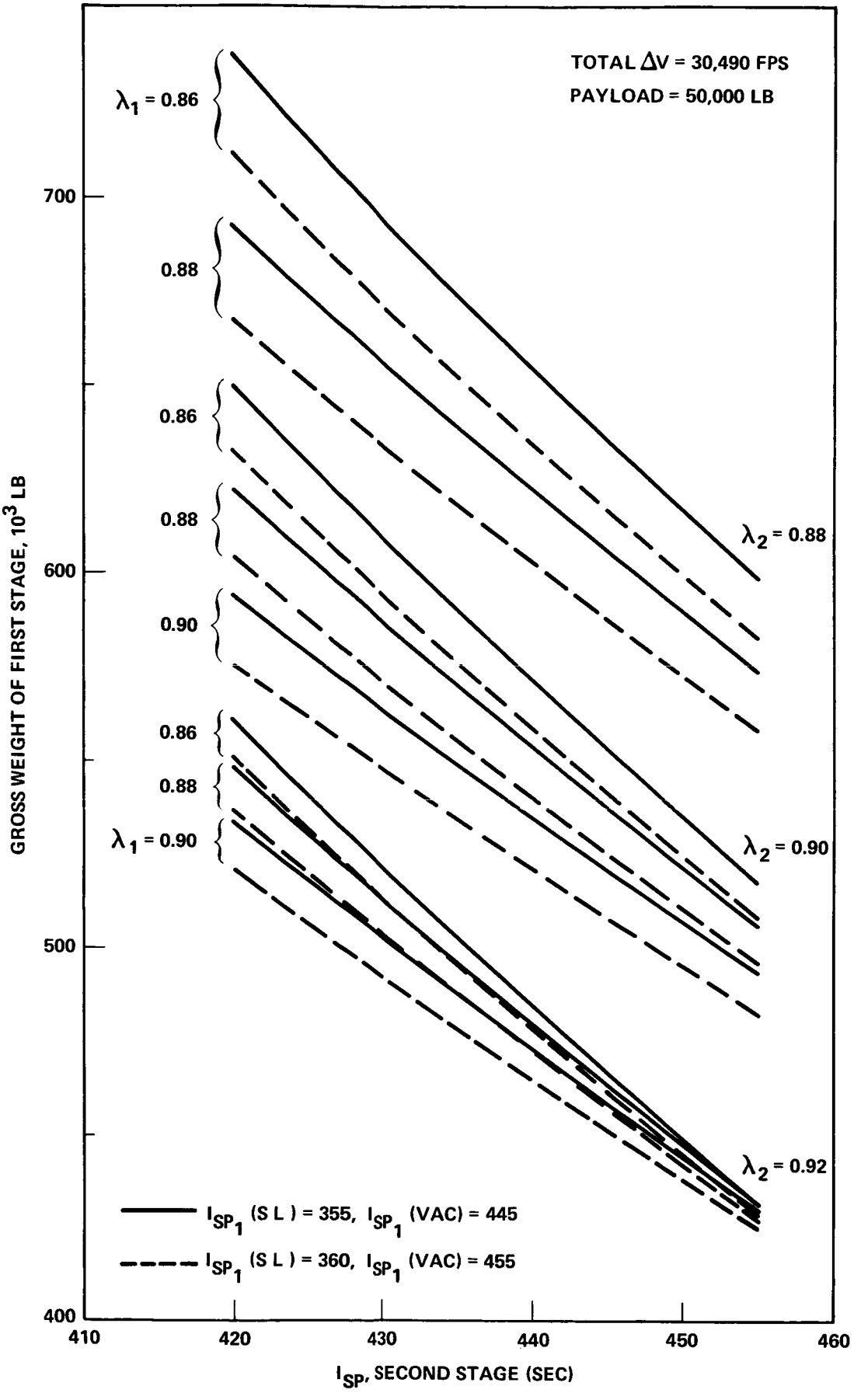

FIGURE 2 - GROSS WEIGHT OF FIRST STAGE vs I_{SP}, SECOND STAGE

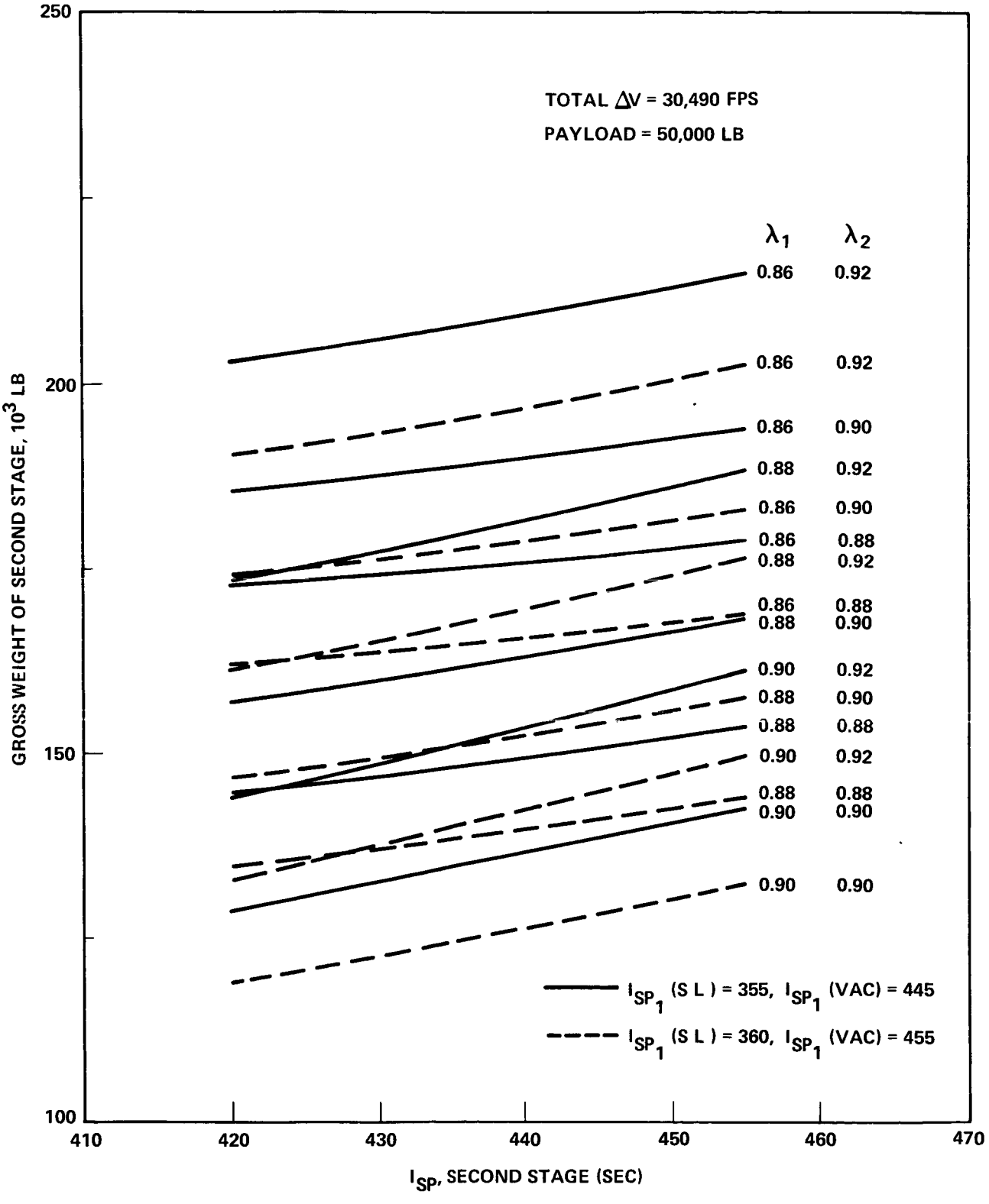

FIGURE 3 - GROSS WEIGHT OF SECOND STAGE vs I_{SP}, SECOND STAGE

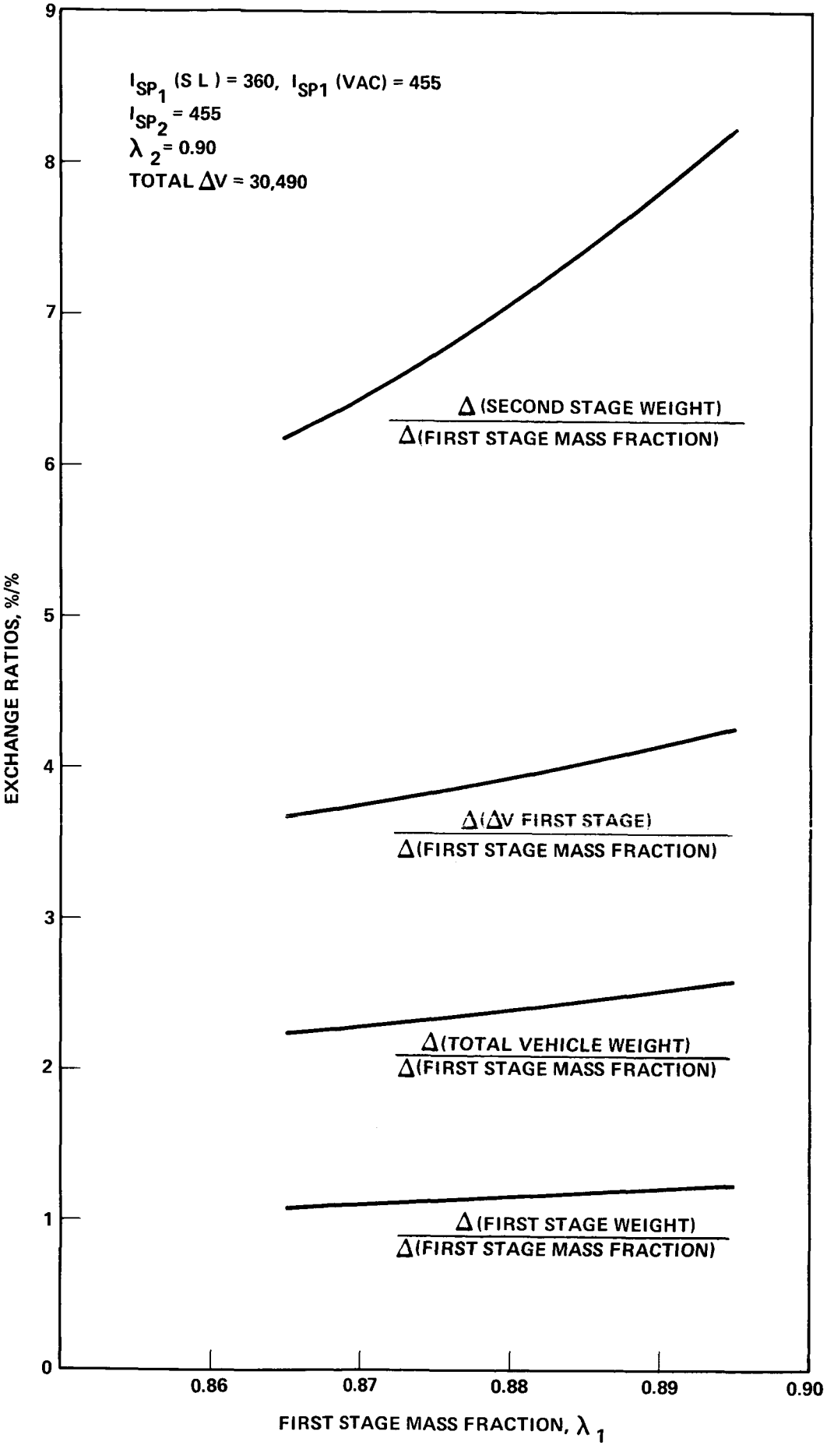

FIGURE 4 - EXCHANGE RATIOS vs FIRST STAGE MASS FRACTION

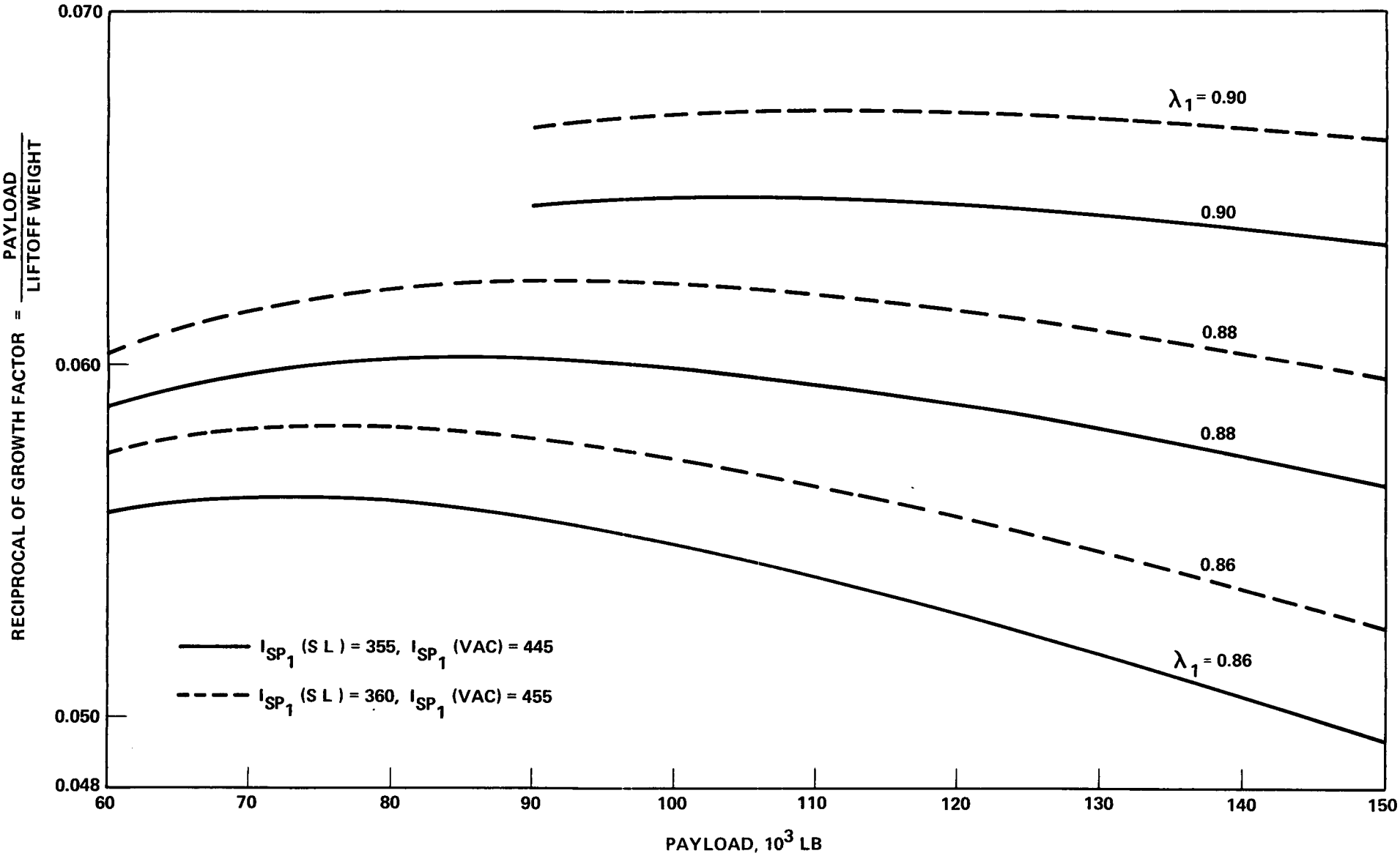

FIGURE 5 - RECIPROCAL OF GROWTH FACTOR vs PAYLOAD
2-STAGE VEHICLE USING THE SIVB AS SECOND STAGE

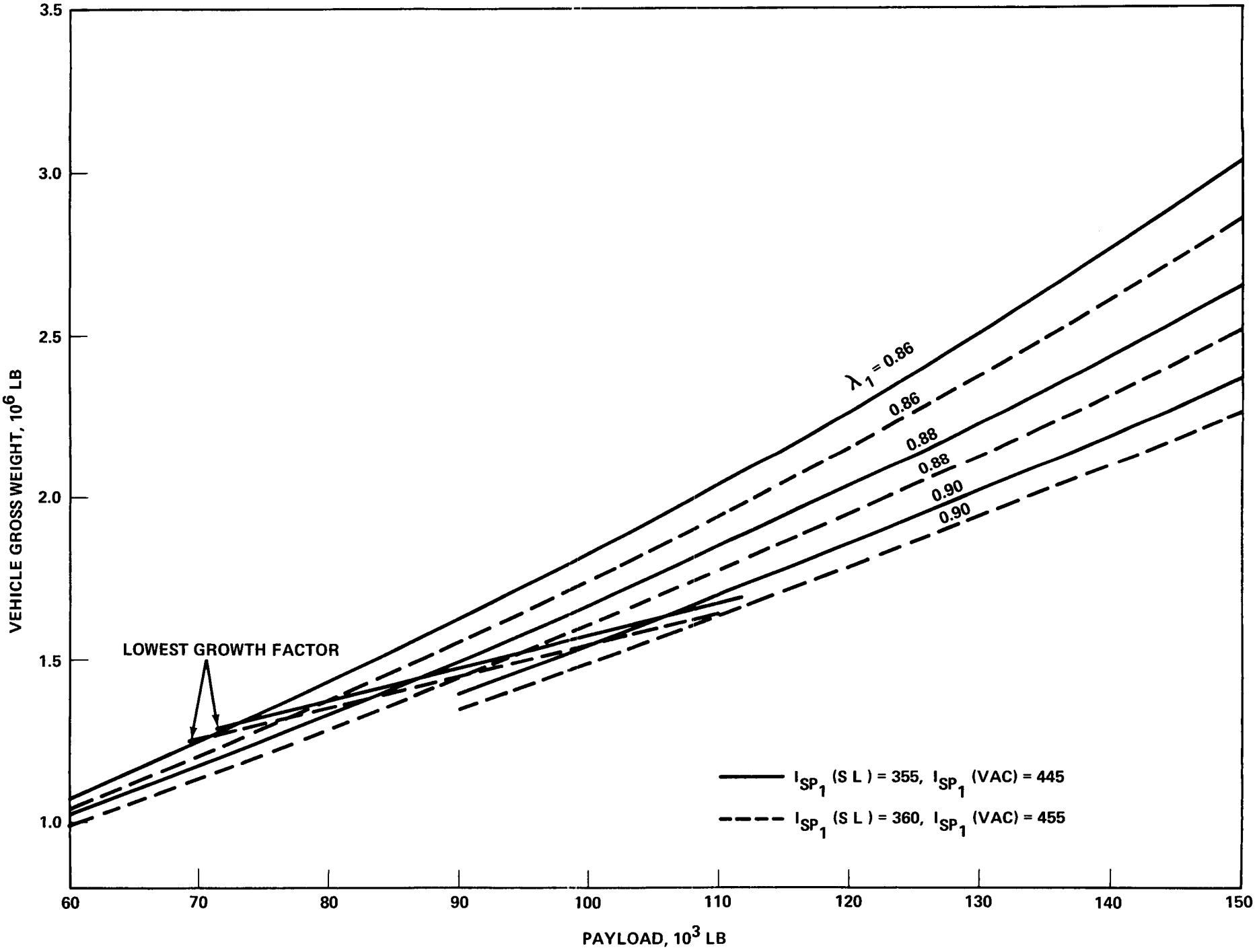

FIGURE 6 - GROSS WEIGHT OF 2-STAGE VEHICLE USING THE SIVB AS SECOND STAGE vs PAYLOAD

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